

Therefore, monitoring and assessing the water quality of lakes and coastal waters is an ideal application of remote sensing. Multi-spectral satellite imagery is a relatively new tool in the aquatic sciences, but since the 1980's when the spatial resolution of remote sensing sensors was reduced, many investigators have used it.

The advantage of using remote sensing techniques for water quality assessment is in providing a synoptic coverage, cost effectiveness, timeliness, ability for quantitative comparisons for numerous water bodies, as well as the need to provide a spatial and temporal variability for fast moving waters. Multi-spectral remote sensing techniques have been used to identify or measure numerous water quality parameters.

In the master thesis an empirical statistical method was used in order to find a possible significant relationship between the TM data and the water quality *in situ* data. It was investigated for a linear relationship and a multiple regression relationship. There was some significant correlation between Chlorophyll and the average between band3 and band4 ($r = 0.622$, at 0.01 level), and between

Secchi Disc Depth and Band4 ($r = -0.506$, at 0.05 level) for the satellite image acquired in 1995; Suspended Sediment and band4 ($r = 0.598$, slightly lower than 0.05 level) for the satellite image acquired in 2000, and for the satellite image acquired in 2001 there was a significant multiple regression established between Chlorophyll and band1, band2, band3 and band4 ($r = 0.931$, at 0.01 level). However, it failed to show any significant relationship for the cases of chlorophyll and Secchi Disc Depth for the image acquired in 2000, and sediment for the image acquired in 2001. For the significant relationships, the prediction models were developed for the water quality parameters, and maps of their distribution were created. Finally, the change analysis was performed for two different dates for maps of distribution of chlorophyll in order to try to show the distribution differences over time. This was the only water quality parameter that was possible to perform change analysis, since it was possible to create the maps of distribution for two different dates. Nevertheless, a methodology using the Erdas Imagine software and the SPSS statistical package was proposed in order to achieve this analysis.

Prepared by M. Lapaine

Tomislav Ciceli, MSc in Technical Sciences

Tomislav Ciceli finished postgraduate scientific studies at the Faculty of Geodesy in Zagreb on November 18, 2004 by defending his master thesis titled *Digital Camera Application in Terrestrial Photogrammetry*. Prof. Dr. Teodor Fiedler was his mentor, and Prof. Dr. Božidar Kanajet and Prof. Dr. Milan Bajić were the members of the commission for the evaluation and defence of the thesis.

Tomislav Ciceli was born in Zagreb on 12th September 1972. He attended and finished the primary school in Sesvete. He graduated from the Secondary Technical School *Nikola Tesla* in Zagreb in 1991. In the same year he enrolled the graduate studies of the Faculty of Geodesy, University of Zagreb. He graduated in 1998 by making a diploma thesis titled *Digital Orthophoto Application in Physical Planning*.

At beginning of 1999 he started to work at the Faculty of Geodesy as an assistant at the Institute of Photogrammetry. The same year he became a student on postgraduate studies at the Faculty of Geodesy, in Zagreb, in the field of Photogrammetry and Cartography. In teaching activity he is responsible for exercises in courses of: Introduction to GIS and Remote Sensing and GIS. As a member of Croatian team CROMAC in the period 2001-2003 he was involved in two international projects sponsored by the European Committee: ARC – Airborne Minefield Area Reduction, and SMART – Space and Airborne Mined Reduction Tools. As a lecturer he

participated in a student GIS seminar GIS: Grab it this summer, with the theme: Photogrammetry & Remote Sensing, Data Sources in GIS. During 2003 he collaborated in the project *Study on aero triangulation and equalization of block of aero photos* made for the State Geodetic Administration. As a member of the Institute of Photogrammetry he was actively engaged in number of professional projects in the field of aerial and terrestrial photogrammetry. His fields of interest are Photogrammetry and GIS and Remote Sensing. He published several papers as a co-author.

His Master's thesis contains 92 pages of A4 format, an appendix of 5 pages, a reference list, an abstract in Croatian and English, a list of 86 illustrations and 29 tables, and short curriculum vitae of the author. The thesis is divided into eleven chapters, as follows:

1. Introduction
2. Digital Camera
3. Evaluation Criteria for Digital Camera
4. Eyesight and Colours
5. Sensors in Digital Cameras
6. Digital Image Formats
7. Digital Camera Calibration in General
8. Application of Digital Camera in Terrestrial Photogrammetry

vremenske varijabilnosti za tekućice. Multispektralne metode daljinskih istraživanja se upotrebljavaju kako bi se identificirali ili izmjerili brojni čimbenici koji utječu na kvalitetu vode.

U magistarskom radu upotrijebljena je empirijska statistička metoda da bi se pronašao mogući značajan odnos između podataka dobivenih iz satelitskih snimaka i podataka s terena. Tražena je linearna veza i višestruka regresija. Pronađena je značajna korelacija između klorofila i sredine između pojasa 3 i 4 ($r = 0.622$, uz razinu 0.01), i između dubine Secchi diska i pojasa 4 ($r = -0.506$, uz razinu 0.05) za satelitske snimke snimljene 1995.; suspendirani sediment i pojas 4 ($r = 0.598$, malo manje od razine 0.05) za satelitske snimke snimljene 2000., a za satelitske snimke snimljene 2001. bila je ustanovljena

značajna višestruka korelacija između klorofila i pojaseva 1, 2, 3 i 4 ($r = 0.931$, uz razinu 0.01). Međutim, nije pokazan nikakav značajni odnos između klorofila i dubine Secchi diska za snimke snimljene 2000., i sedimenta za snimke iz 2001. Za značajne odnose razvijeni su modeli predikcije za parametre kvalitete vode i kreirane su karte njihove raspodjele. Na kraju, provedena je analiza promjene za dva različita datuma za karte raspodjele klorofila da bi se pokušala prikazati razlika u raspodjeli nastala s vremenom. To je bio jedini parametar kvalitete vode za koji je bilo moguće napraviti analizu promjene, jer je bilo moguće kreirati karte raspodjele za dva različita datuma. Analiza je izvedena upotrebom softvera Erdas Imagine i statističkog paketa SPSS.

Pripremio M. Lapaine

Tomislav Ciceli, magistar tehničkih znanosti

Tomislav Ciceli završio je poslije-diplomski znanstveni studij na Geodetskom fakultetu u Zagrebu 18. studenog 2004. obranom magistarskog rada pod naslovom *Primjena digitalne kamere u terestričkoj fotogrametriji*. Rad je izrađen pod mentorstvom prof. dr. sc. Teodora Fiedlera, a u povjerenstvu za ocjenu i obranu rada bili su još prof. dr. sc. Božidar Kanajet i prof. dr. sc. Milan Bajić.



Tomislav Ciceli rođen je 12. rujna 1972. godine u Zagrebu. Osnovnu školu pohađa i završava u Sesvetama. Srednjoškolski obrazovni centar *Nikola Tesla* u Zagrebu završava 1991. Iste se godine upisuje na dodiplomski studij na Geodetskom fakultetu Sveučilišta u Zagrebu. Izradom diplomskog rada iz fotogrametrije pod naslovom *Primjena digitalnog ortofota u prostornom planiranju* 1998. stiče titulu diplomiranog inženjera.

Početkom 1999. godine zapošljava se na Geodetskom fakultetu kao mlađi asistent u Zavodu za fotogrametriju. Iste godine upisuje poslijediplomski studij na Geodetskom fakultetu usmjerenje Fotogrametrija i kartografija. U nastavi je držao vježbe iz sljedećih kolegija: Uvod u GIS, Daljinska istraživanja i GIS. Kao član hrvatskog tima CROMAC u razdoblju od 2001. do 2003. godine sudjeluje na dva međunarodna projekta: ARC – Airborn Minefield Area Reduction, znanstveno-stručni projekt Europske komisije i SMART – Space and Airborn Mined Reduction Tools, također znanstveno-stručni projekt Europske komisije. Kao predavač 2002. sudjeluje na međunarodnom studentskom seminaru o GIS-u: GIS – Grab it this Summer s temom predavanja Photogrammetry & Remote Sensing; data sources in GIS. Tijekom 2003. surađuje na projektu *Studija o aero-triangulaciji i izjednačenju bloka aero-snimaka* izrađenom

za potrebe Državne geodetske uprave. Kao djelatnik Zavoda za fotogrametriju Geodetskog fakulteta aktivno je učestvovao u izvedbi raznih stručnih projekata iz područja aero i terestričke fotogrametrije. U dosadašnjem znanstvenom radu bavi se fotogrametrijom, daljinskim istraživanjima i GIS-om. U koautorstvu je objavio nekoliko radova iz tih područja.

Magistarski rad sadrži 92 stranice formata A4, 5 stranica priloga, popis literature od 89 radova, sažetak na hrvatskom i engleskom jeziku, popis 86 slika i 29 tablica, te kratak životopis autora. Rad je podijeljen u jedanaest poglavlja:

1. Uvod
2. Digitalna kamera
3. Kriteriji za procjenu digitalne kamere
4. Vid i boje
5. Senzori u digitalnim kamerama
6. Formati zapisa digitalnih snimki
7. Općenito o kalibraciji kamere
8. Primjena digitalne kamere u terestričkoj fotogrametriji
9. Kalibracija digitalne kamere Fuji FinePix S2 Pro
10. Zaključak
11. Literatura

U uvodu je dan kratak pregled razvoja fotogrametrije s naglaskom na digitalnu fotogrametriju. Navedena je problematika koja se obrađuje u radu i što se radom želi postići.

9. Calibration of Fuji FinePix S2 Pro Digital Camera

10. Conclusion

11. References

Introduction gives a short overview of photogrammetry development, with accent on digital photogrammetry. The problems that the Master's thesis is dealing with and what is intended to be done is also mentioned.

In the next chapter, an overview of main characteristics of digital cameras is given; sensor dimensions, picture element size, number of picture elements and classifications of digital cameras. Cameras are divided in two main groups: metric and non-metric, with their characteristics.

In the third chapter there is a proposal of some basic criteria for evaluation of quality for non-metric digital cameras, because there was a premise that metric cameras already meet these criteria.

The fourth chapter describes main characteristics of human vision used in production of digital camera sensors. Details of two main colour spaces, RGB and IHS, are also given.

The fifth chapter is the most comprehensive. It gives a detailed description of the main difference between analogue and digital cameras – the sensor. Three main types of sensors: CCD, CMOS and LBCAT JFET are described. Characteristics, similarities, differences and main advantages and disadvantages of all three sensors are given.

In the sixth chapter there is a short overview of main digital image formats.

The next chapter deals with camera calibration from a theoretical point of view. Classification of calibration

by type is made. Geometrical laws of creating images passing through optical system, and deformations are described in detail.

An overview of possible applications of digital cameras in terrestrial photogrammetry is made in chapter eight. Advantages of using digital images during the work in the field are shown. A rough estimation of savings in the first phase of the project and possible applications in realization of the project are reported.

The ninth chapter represents the practical part of this master thesis: the establishment of calibration field and the calibration of digital camera Fuji FinePix S2 Pro with SIGMA DG 20 mm interchangeable lens. The coordinates of 56 points are defined with geodetic measurements in the field and for calibration. It is shown that the calibration of camera presents the primary step in using amateur camera for measuring purposes in photogrammetry. Expected basic parameters of interior orientations, and parameters of lens distortion are also defined. After the calibration was done, a photo triangulation was performed in order to calculate the coordinates of used points. Some of these points were used like unknown points, and after the photo triangulation was finished, a comparison between these new and known coordinates was made. With this comparison the quality of camera calibration was assessed.

A conclusion of the master thesis made after the overview of used technology and conducted research offers some basic rules in the selection of an amateur digital camera for photogrammetric purposes. It was shown that basic knowledge of sensor technology with good calibration of camera could turn the amateur digital camera in a high quality instrument for collecting spatial data in terrestrial photogrammetry.

Prepared by M. Lapaine

Branimir Majčica,

Master of Land Management

Branimir Majčica defended his master thesis *Improvement of the System of Land Registration in Croatia, Towards One-Stop-Shop Solutions* in the Centre of Land Management and Land Tenure, Technische Universität München on 28th February 2005. His tutors were Univ.-Prof. Dr.-Ing. Holger Magel and Dr.-Ing. Michael Klaus from the Technical University in Munich, and Prof. Dr. Miodrag Roić from the Faculty of Geodesy, University of Zagreb. By the certificate of the Agency for Science and Higher Education of the Republic of Croatia of 18th July 2005, the foreign high education qualification of Master of Science is admitted to Branimir Majčica completely. This diploma is equalized in Croatia referring to its rights with the diploma of the graduate university

studies providing the academic title master (*magistar in Croatian*) of land management.

Branimir Majčica was born on 7th December 1973 in Požega. He visited the Italian primary school Galileo Galilei in Umag. In Zagreb he visited Xth high school, the school of natural sciences and mathematics. He graduated in 1992 and enrolled the Faculty of Geodesy at the University of Zagreb and graduated from it in 1999. In 1998 he enrolled the Faculty of Philosophy of Družba Isusova in Zagreb. From 2003 he studied as a scholarship holder of DAAD (Deutscher Akademischer Austauschdienst) at the postgraduate master studies Land Management and Land Tenure in the Centre for Land

U sljedećem je poglavlju napravljen pregled glavnih osobina digitalnih kamera kao što su dimenzija senzora, veličina slikovnog elementa i broj slikovnih elemenata. Izrađena je klasifikacija digitalnih kamera. Napravljena je podjela kamera na dvije osnovne cjeline: mjerne i nemjerne, i detaljno su opisane njihove karakteristike.

Treće poglavlje predlaže nekoliko osnovnih kriterija za procjenu kvalitete digitalnih kamera koji se primarno odnose na amaterske kamere jer se kreće od pretpostavke da mjerne kamere zadovoljavaju te kriterije u samom početku.

Četvrto poglavlje sadrži sažet opis osnovnih osobina ljudskog vida, a koje se nastoje reproducirati u sensorima korištenim u digitalnim kamerama. Također su detaljno opisana i dva osnovna sustava boja: najčešće korišten RGB, te sustav koji je primjereniji ljudskom vidu IHS.

Peto, i najopširnije poglavlje potanko opisuje glavnu razliku između analognih i digitalnih kamera – senzor. Opisana su tri osnovna tipa senzora: CCD, CMOS i LBCAT JFET senzor. CCD, kao još uvijek najčešći senzor je detaljno opisan. Opisani su principi rada, različitosti izvedbe, nastajanje boje. CMOS i LBCAST JFET senzori opisani su u svojim glavnim razlikama u odnosu na CCD, jer postoji velik dio sličnosti između njih i CCD senzora, primarno u izvedbi i nastajanju boja.

Šesto poglavlje je kratki osvrt na formate zapisa digitalnih snimki, njihove osnovne razlike i sličnosti.

Kako je praktični dio ovoga rada kalibracija digitalne kamere, u sedmom poglavlju su iznesene teoretske osnove, kao i podjela kalibracija prema vrsti. Opisane su detaljno geometrijske zakonitosti nastajanja snimke

prolaskom kroz optički sustav, kao i deformacije koje nastaju na tom putu.

Osmo poglavlje je pregled mogućnosti uporabe digitalne kamere u terestričkoj fotogrametriji. Istaknute su prednosti korištenja slike već prilikom snimanja na terenu, a naročito u pripremnoj fazi rada. Dane su grube procjene novčanih ušteda nastalih uporabom digitalne kamere u preliminarnoj fazi projekta, kao i razrada primjene u izvedbenoj fazi.

Deveto poglavlje opisuje praktični dio rada koji se sastojao od uspostavljanja polja za kalibraciju kamere, te kalibracije digitalne kamere Fuji Fine Pix S2 u kombinaciji s objektivom SIGMA DG 20 mm. Geodetskim mjerenjima određenu su koordinate 56 točaka polja za kalibraciju. Pokazano je da je kalibracija kamere temeljni korak u primjeni amaterske kamere u mjerne svrhe u fotogrametriji. Osim osnovnih parametara unutarnje orijentacije izračunani su i parametri distorzije upotrijebljenog objektiva. Ponovnim računanjem koordinata s tako izračunanim parametrima ponovno su izračunate koordinate određenog broja točaka koje su uzete kao nepoznate. Analizom tako dobivenih rezultata ocijenjena je kvaliteta kalibracije.

Zaključak u radu na osnovu iznesenog pregleda tehnologija, kao i provedenog istraživanja nudi nekoliko osnovnih pravila za izbor amaterske kamere u fotogrametrijske svrhe. Pokazuje se da osnovna poznavanja rada senzora u kombinaciji s kalibracijom kamere mogu kvalitetnu amatersku kameru pretvoriti u kvalitetan instrument za prikupljanje podataka u fotogrametriji.

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Branimir Majčica, magistar zemljišnog menadžmenta

Branimir Majčica obranio je 28. veljače 2005. magistarski rad *Improvement of the System of Land Registration in Croatia, Towards One-Stop-Shop Solutions* (Poboljšanje zemljišnoknjižnog sustava, Prema rješenju "sve na jednom mjestu") u Centru za zemljišni menadžment i zemljišno pravo Tehničkog sveučilišta u Münchenu. Mentori su bili Univ.-Prof. Dr.-Ing. Holger Magel i Dr.-Ing. Michael Klaus s Tehničkog sveučilišta u Münchenu te prof. dr. sc. Miodrag Roić s Geodetskog fakulteta Sveučilišta u Zagrebu. Rješenjem Agencije za znanost i visoko obrazovanje RH od 18. srpnja 2005. Branimiru Majčici priznaje se u cijelosti inozemna visokoškolska kvalifikacija Master of Science. Ta je diploma u Hrvatskoj izjednačena u pravima s diplomom diplomskog



sveučilišnog studija čijim se završetkom stječe akademski naziv magistar (mag.) zemljišnog menadžmenta.

Branimir Majčica rođen je 7. prosinca 1973. u Požegi. Talijansku osnovnu školu Galileo Galilei pohađa u Umagu. U Zagrebu pohađa X. gimnaziju, prirodoslovno-matematičku. Maturira 1992. godine i upisuje se na Geodetski fakultet Sveučilišta u Zagrebu, gdje diplomira 1999. god. God. 1998. upisuje studij filozofije na Filozofskom fakultetu Družbe Isusove u Zagrebu gdje je apsolvant. Od 2003. kao stipendist zaklade DAAD (Deutscher Akademischer Austauschdienst) studira na poslijediplomskom magistarskom studiju Zemljišni menadžment i zemljišno